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X-RAY PHOTO SYSTEM FOR HIGH VELOCITY FREE FLIGHT MODELS

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X-RAY PHOTO SYSTEM FOR HIGH VELOCITY FREE FLIGHT MODELS

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Several methods have been used in the Free-Flight ranges for detecting rapidly moving test models of various sizes, either for direct velocity measurements or to trigger photographic systems. The most common method is the transmission type optical photo beam, either as a single-pass, or as a multiple-pass light curtain. Other methods used are the breakwire, electrostatic or magnetic pickups, light emission from an aerodynamically heated model, and pressure transducers which respond to the shock wave from the moving model.

All of these detection methods encounter difficulties under certain conditions. For transmission optical photo-beams, smoke and light from the launch system, as well as shock waves and light emitted from the model, interfere with the photo-beam. Light emission (or light increase) methods are sensitive to the same disturbances, and are further limited by the large variation in intensity of emitted light from the model, depending on test conditions. A disadvantage of break-wires is that they interfere with the model trajectory. Electric and magnetic pickups are not very precise. With pressure transducer detection methods, the output amplitude and timing vary greatly with test conditions.

A problem existed in a high-speed model-launch system for which these methods of model detection were unsatisfactory. Improper model-sabot separation was suspected as the cause for off-trajectory flights. Further study of the model-sabot separation phenomena required photographs to be taken at the launch muzzle exit. However, light and smoke from the launch system negates use of optical photo-beam detection methods and also light photography. It was for this purpose that the X-ray trigger beam and X-ray flash photography system was considered and its development undertaken. Such a system is insensitive to light, shock waves, and smoke from the launch gun. It has a fast response and is therefore a precise trigger. Also, the model is unaffected by the trigger system. A further advantage of the flash X-ray photograph is that a model more dense than its sabot will be visible within its sabot.

The X-ray photo system used in the Ames Free Flight facilities consists essentailly of two X-ray systems, the X-ray trigger system and the high voltage flash X-ray photographic system shown in block diagram in figure 1. The X-ray trigger system consists of an X-ray generator, 0-20 KV, which generates a steady X-ray beam across the model path, a scintillation photo-multiplier detector in the beam path, a dc preamp to amplify the detector output, and a Schmidt-trigger thyratron-pulser to generate the trigger pulse for the high voltage flash X-ray unit.

The X-ray trigger beam generator uses a Machlett EG 25E X-ray tube, rated at 25 KV and 10 milliamps. The filament and the thin beryllium transmission window are at ground potential. The tube is enclosed in a 3" diameter housing, a concentric brass tube within the 3" housing carrying filament current from the cable entrance to the X-ray tube filament. O-ring seals are used to make the housing oil tight so that it may be filled with transformer oil for adequate cooling of the unit during continuous operation. An 8 amp, 5 volt, dc source controlled by a variac supplies filament current for the X-ray tube. DC is needed because experiment showed the heat capacity of the 25 E filament is so low that a 60 cycle fil. source imposes considerable 120-cycle modulation on the X-ray trigger beam. The X-ray trigger-beam generator is powered by a 0 to 30 KV, 25 milliamp power supply.

The X-ray trigger beam detector uses a Na I-Th crystal 1/16" thick and 1" diameter. Its light output is monitored by a ten-stage photomultiplier. The electrical signal thus generated is fed into a transistorized, dc amplifier with an output impedance low enough to drive a 70 foot, 100 ohm coax line leading to the Schmidt trigger circuit. The dc signal affords a convenient way to set up the trigger intensity just prior to model launch. The Schmidt trigger output fires a thyraton pulser which in turn triggers the high voltage flash X-ray equipment.

Included is an X-ray alarm and high voltage control system which operates a bell and flashing light for 10 seconds before and during the period when either the X-ray trigger beam high voltage, or the flash X-ray high voltage is on. Included also is a high voltage pulse generator which, when triggered by a test button, cuts off the X-ray beam momentarily, thus simulating passage of a model through the beam. This affords a check on the AC response of the detector-trigger system.

A flash X-ray system by Field Emission Inc. is used to take X-ray photographs of the model and sabot in flight. It provides an X-ray pulse of approximately 30 nanoseconds duration and intensity up to 10^8 roentgens/sec, at voltages from 50 KV to 105 KV. A delayed trigger amplifier provides a 12 KV delayed pulse sufficient to trigger the flash X-ray unit. The delay is variable from 0 to 1,000 microseconds and is convenient for taking pictures up to a few feet downstream from the X-ray trigger beam.

The high velocity X-ray photo system built at Ames utilizes two X-ray trigger beams and two independently triggered Flash X-ray units; thus allowing two widely spaced X-ray photographs of the model in flight. The two X-ray trigger systems utilize the same 30 KV, 25 ma supply but are otherwise independent. Figure 2 show sample photographs obtained with this unit. One good launch and one poor launch are shown.

Experience with this equipment has shown that considerable care in allignment of the X-ray trigger beam and adjustment of parameters is necessary to achieve reliable results. Plastic sabots and often plastic models are fired in our Supersonic Free Flight Range. Their absorption coefficients for 20 KV X-rays are low, but increase rapidly as the X-ray voltage is reduced to about 14 KV. Since the trigger signal depends upon absorption of the primary trigger beam by the model, choice of X-ray voltage is important. There is also an appreciable statistical noise inherent in the X-ray trigger beam. Accepted practice is to experiment with a given model material to determine the optimum X-ray voltage, intensity, and detector sensitivity for the highest signal to noise ratio as the model interrupts the beam. With proper care in allignment of the trigger beam and adjustment of the electronic parameters, and with the trigger beam placed a few inches in front of the launch muzzle, 100% reliability has been achieved.

A direct result of the noise content is that use of the instrument is restricted to the area near the launch muzzle where the model is sure to interrupt a large fraction of the X-ray trigger beam. The spread in the possible model trajectory further downstream requires a wider X-ray trigger beam, resulting in an unacceptably low signal-to-noise ratio.

Regarding the flash high X-ray voltage system, experience has shown that good contrast X-ray photographs are obtained over the 80 KV to 100 KV range for all the models and sabot materials used so far.

A method of model detection using scattered X-rays rather than an interupted X-ray beam, has been considered. Its chief advantage is an improvement in the signal to noise ratio. This allows its use much farther downstream from the launch gun, where the spread in the possible flight trajectory may be many times the model size.

Calculations were made to determine the requirements for detecting a 0.4 cm diameter sphere of Lexan plastic, moving through 1 atm of air at 20,000 ft/sec, within a circle 4 in. in diameter. A system to suit this "worst case" would utilize a pulsed primary X-ray beam of 10 milliseconds duration and with an X-ray potential of 100 KV to 160 KV. To achieve the necessary scattering intensity, a peak emission current of 1 amp is required. To detect the scattered X-rays after collimation, several NaI-Th scintillation crystals approximately 2 cm thick would be used. A total detection area of 10 cm^2 and 15 cm from the flight path would be sufficient.

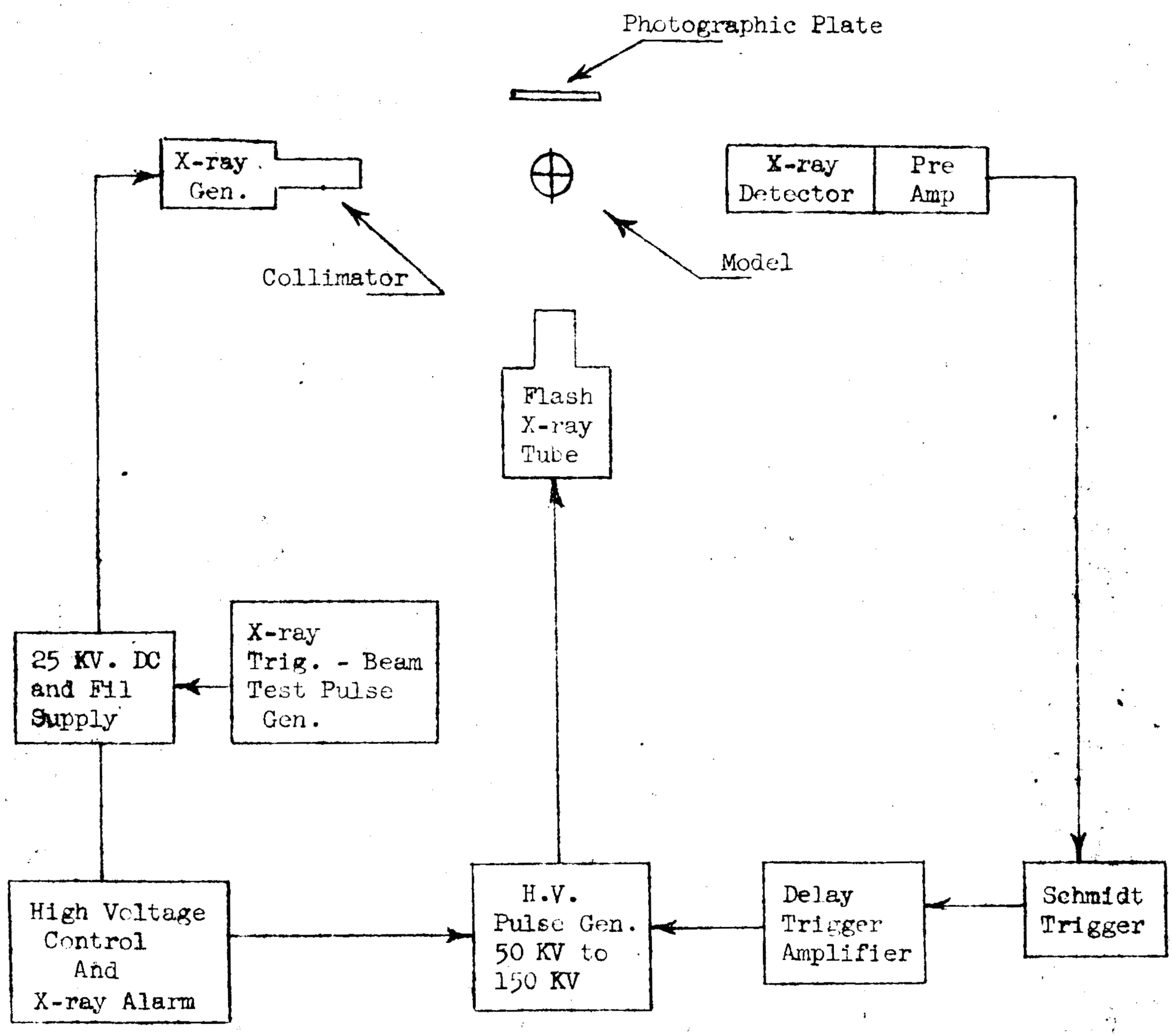

Figure 1 - Block Diagram of Hi-Velocity X-ray Photo System.

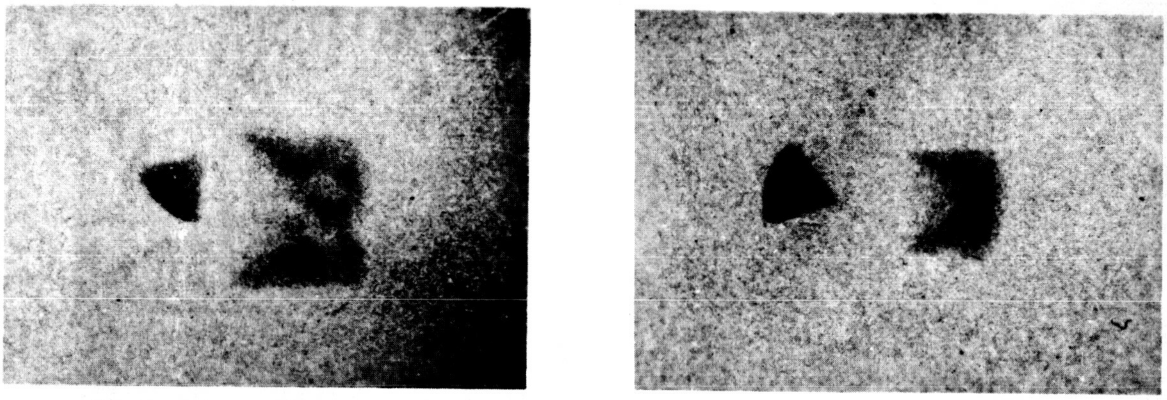

Figure 2.- Flash X-ray photographs of models.